Vol. III. OCTOBER, 1886. No. 6.

American Meteorological Journal.

A Monthly Review of Meteorology, Medical Climatology and Geography.

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ANN ARBOR, MICH., U. S. A.:
METEOROLOGICAL JOURNAL COMPANY.
19, 21 and 23 Huron Street.

F. A. BROCKHAUS, Leipsic, Berlin, and Vienna, Agent for German and Austrian States.
Single Copies, 25 cents. Per Annum, $2.00. In European Countries $2.25.

Entered at the Ann Arbor Postoffice as Second Class Matter.

AMERICAN METEOROLOGICAL JOURNAL.

AN ILLUSTRATED MONTHLY

DEVOTED TO SCIENTIFIC METEOROLOGY AND ALLIED BRANCHES OF STUDY.

THE AMERICAN METEOROLOGICAL JOURNAL CO., Publishers and Proprietors,
Ann Arbor, Michigan.

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PRICE,—IN THE UNITED STATES. - - - - $2.00 per year
" IN COUNTRIES OF THE POSTAL UNION, - - 2.25 " "

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CURRENT NOTES.

THE SCIENTIFIC SOCIETY "ANTONIO ALZATE" recently organized in the City of Mexico, has published the first part of its memoirs. The pamphlet contains an article by Don Rafael Aguilar on ozone, summing up what is known on the subject, and a mathematical study on the variability of functions by Don Manuel Marroquin y Rivera. At the end is a graphic and numerical *resumé* of meteorological observations in Mexico (city) for 1883.

THE PRINCIPLES OF WEATHER FORECASTING are given by Mr. Abercromby in No. 60 of the official publications of the British Meteorological Council. The thick octavo pamphlet of 124 pages is thoroughly illustrated by cuts and gives in consecutive order and easily comprehensible manner the principles on which weather charts are used. There is a similar publication in German, by Baron Friedenhof, and an American one by Mr. Bassler, of Cincinnati. Mr. Abercromby's pamphlet is much more complete than either of the others, and, while much of it is of only local application, it still deserves to be in the hands of American students.

THE ANNUAL OF THE MICHIGAN STATE BOARD OF HEALTH for 1885 is now out. It is, in form and matter, uniform with the already long row of its predecessors, but shows several improvements. The most of the report is written by the secre-

tary, Dr. H. B. Baker. Eight pages are devoted to poisonous cheese by Drs. Sternberg and Vaughan. Testing illuminating oils in Michigan, and state inspection of travel, are two noteworthy articles. We doubt if any state equals Michigan in the activity of its state board, and, it is fair to say, in this state the activity is largely due to Dr. Baker.

AN ERROR.—A reader kindly points out an error on page 205 of this volume of the JOURNAL. It is there said that Leadville is more than twice as high as Mt. Washington. This is incorrect; Mt. Washington is, according to Guyot, 6,288 feet high, or according to the Appalachian club, 6,286 feet.

BOOK CHAT.—This little monthly gives a classified list of articles appearing monthly in over 150 periodicals. We find it very useful in keeping track of periodical scientific literature and we have no doubt our readers would find it advantageous.

THE SANITARY CONVENTIONS of the Michigan State Board of Health deserve special commendation. Several times a year a committee of this board organizes a convention in the various cities and villages of the state in which various questions of general or local interest are discussed. The convention serves both to instruct, and to create and keep alive a healthy public sentiment on sanitary matters. The proceedings and addresses are noticed by the newspapers and afterwards published and distributed in pamphlet form by the board. We have before us the pamphlet for the Howell convention on March 3rd and 4th, and that of the Kalamazoo convention on June 1st and 2nd, both of this year. They form octavo pamphlets of 60 and 74 pages respectively.

THE LICK OBSERVATORY.—Professor E. S. Holden, who has recently been appointed director of this observatory and president of the University of California, will undoubtedly do noteworthy work in both capacities. We refer here, however, to the subject, not so much to record Mr. Holden's accession to

this double responsibility, as to note the liberal spirit in which he undertakes his trust. Appreciating that the Lick observatory, by its elevated position and large instrument, offers unsurpassed opportunities for observation, Mr. Holden freely offers its use, under some necessary restrictions, to astronomers generally. This shows the proper scientific attitude where the advancement of science is of more consequence than personal distinction. This is by no means a rare attitude among scientific men; the same spirit is seen in the unwritten law of scientific ethics, which requires that purely scientific instruments shall not be patented, but shall be left freely to the use of all who can make use of them. Professor Holden's offer deserves notice simply because it is a noteworthy case on account of the exceptional character of the opportunity offered.

PROFESSOR WM. FERREL has, we regret to learn, resigned from the Signal service. His future address will be Kansas City, Missouri. Prof. Ferrel's resignation was evidently due to the completion of work on which he was engaged. That he was not engaged for a longer time seems to have been due to insufficient appropriations. It is very much to be regretted that, with the large surplus the government has, it cannot afford to take good care of its scientific services. An economy which will permit the government to lose men of such ability and reputation as Professor Ferrel is a false one, and much to be deprecated. Professor Ferrel has been engaged on a tide gauge for the Coast Survey. This is now complete and ready for use. He has also completed a treatise on Meteorology which is, we believe, ready for the printer. The treatise is the property of the Signal Service and it is to be hoped that it will soon see the light.

THUNDERSTORM PERIODS IN WINTER.—Dr. Hann calls attentention to some notable features of thunderstorms at Vienna. In early summer these storms are apt to reach Vienna from the east or southeast. The eastern thunderstorms cease in the latter part of June and occur only when a center of low pressure passes from the Northern Atlantic to Hungary. It would be

interesting to learn if we have thunderstorms from the east in this country. The writer has no record of them at Ann Arbor for seven years.

In observations for thirty-two years Dr. Hann finds two annual maxima for the number of storms. One falls in the first half of June, the other in the latter half of July. The same is true for other parts of Germany, and even for Brussels, except that in the last case the first maximum falls in the latter half of June.

From the annual totals it appears that there is no good foundation for the idea that thunderstorms are growing more common. The average for Vienna is 17. In 1880 there were 28 and in 1859 and 1868, 27 each. In 1856 there were only 5 noted and in 1882, 12.

There is also a double daily maximum for these storms. Their greatest frequency is at 3h 20m in the afternoon and the second maximum falls from 1 to 2 in the morning. The greatest freedom from thunderstorms occurs from 7 to 10 in the morning. The southwest thunderstorms are likely to occur earliest in the afternoon, the northeast ones latest.

A Prize for a Model Tornado Cellar.—A hiding place from the wind was what the prophet of old sighed for, and a strong tower into which he might run and be safe was the desire of the wise man three hundred years before the prophet! From the earliest days down to the present the mighty power of the wind has been recognized, and shelter from its destructive force has been sought by the children of men. A practical turn has been given to this general desire by the Burlington Insurance Company of Iowa in an offer which it has made of a prize of two hundred dollars for the best plan of a tornado cave. Designs will be received by that company up to December 15, when they will all be submitted, unopened, to Lieut. John P. Finley, of the U. S. Signal Service at Washington, who will make the award upon merit, and the $200 will then be paid by the company. This is a remarkably happy thought. As the great Northwest becomes more thickly peopled, the effects of destructive winds

are more frequently felt. So far as we know, the winds have always blown there, but the people were not there to be hurt, and so attention has not been especially directed to these storms until within the last score or so of years. Now the destruction of property each year by tornadoes is very considerable; this can be provided for to a certain extent by insurance and the property can be replaced, but the lives which are lost in these terrible wind storms cannot be recalled, and he who sets in motion a plan for the better protection of human life when the tornado is abroad is a benefactor to the race. The Monitor has always taken a lively interest in the tornado question and its relations to insurance, and it notes with peculiar satisfaction the forward position of President John G. Miller, of the Burlington Insurance Company in thus offering a stimulus to competitive effort for the production of the best practical plan of a tornado cave. —*Insurance Monitor.*

The Hong Kong Weather Service.—There is an active, East-asiatic service to which we have made occasional reference. It is under the direction of Dr. W. Doberck, government astronomer at Hong Kong, and the reports are made to the Hong Kong Observatory. The stations reporting are 45 in number, extending from the Philippine Islands and Cochin China to Wladiwostock in Mantchouria. The stations are nearly all coast ones, but there are five on the Yang-tse-Kiang river, of which the most distant is Ichang, about 700 miles up the river. Five stations are in Formosa and, of the Japanese stations, Nagasaki reports to Hong Kong; two stations are in Korea.

The Hong Kong station itself is well supplied with instruments, including those for magnetic determinations. The first volume of observations and researches was published in July of last year. The attempt of the service is to cover the region of typhoons on the west Pacific coasts not already covered by the Japanese service. Daily weather reports and storm warnings have been issued, though with insufficient clerical aid. A peculiar feature of the instrumental outfit is the "rotating" dry

and wet bulb thermometer, a description of which is to be found in the annual report for 1885. Sunshine observations are taken and observations on upper clouds are made every three hours.

Especial attention is paid to typhoons, of which nine were observed from July to November, 1885. Several of them were closely followed for several days. The following rule and comments for finding the center of a typhoon will be of interest:

Vessels in the China sea are generally enabled by observing the rules given in the notices of the 11th May, and the 16th July, 1885, to avoid running into typhoons, that may be encountered. In the former notice the following rule is given:

"The whereabout of the centre of a typhoon may, in the China Sea, be ascertained by the rule:—stand with your back to the wind and you will have the center on your left side, but between two and four points in front of your left hand. There are, however certain exceptions to this rule. Thus there often blows a steady easterly gale along the southern coast of China, when a typhoon is crossing the China sea, and the gale blows often steady from Northeast about the northern entrance to the Formosa straits, when there is a typhoon in a more southern latitude."

An illustration of this rule is contained in the Weather Report for August, 1884, published on the 3d April, 1885.

Further researches have shown, that in the Philippine Islands and along the Coast of China as far north as 24° latitude when you stand with your back to the wind in a typhoon, you will probably have the center nearly 4 points in front of your left hand, but on the open sea far from any shore you will generally have it about 3 points in front of your left hand when your ship is in front of the centre of the typhoon, and more than three points in front of your left hand behind the centre. Above 25° latitude the angle will probably be found to be between 2 and 3 points. It appears to be smaller the greater the distance from the nearest shore and the greater the latitude. At some distance behind the centre the wind blows generally straight towards it.

AN INVESTIGATION OF CYCLONIC PHENOMENA IN NEW ENGLAND.

The local weather services of the United States are rapidly collecting from their numerous observers a mass of material which can be made the bases of valuable researches. The U. S. Signal Service, with its stations scattered over the whole country, investigates meteorological phenomena on a large scale,

taking a comprehensive but necessarily general survey of the field. The local services, which may have a larger number of observers in a single State than the general service has in all the States of the Union, are in a position to supplement the work of the government by filling in the minute details of its investigations. The New England Meteorological Society acts as the local weather service for New England, and desires not merely to collect and tabulate meteorological observations, but to use the material thus obtained for subsequent study. The data collected by this society relate primarily to precipitation and temperature, but little attention having been directed to other subjects; the observations of the former include not only amounts and character, whether rain or snow, but also the times of beginning and ending of the precipitation, while a clear separation is maintained between the records of rain and snow, on account of the difficulty and oftentimes the impossibility of measuring the latter with accuracy. As the work of the society is wholly voluntary, it is not possible to secure complete returns from all observers, but a large number of the observers are careful to record all that is asked, and to observe on the uniform plan recommended. The distribution of the observing stations is necessarily uneven, from a geographical standpoint, but the closeness of the stations in eastern Massachusetts is an advantage for minute study over this limited area. The Bulletin of the Society for July, 1886, embraced reports from 151 observers, distributed as follows: 14 in Maine, principally in the southwesten portion of the state, 21 in New Hampshire, 14 in Vermont, 68 in Massachusetts, 9 in Rhode Island, 15 in Connecticut, 8 in New York east of the Hudson and 2 in New Brunswick.

The investigation described in this paper is an attempt to make use of the material collected by the observers in New England as far as it relates to precipitation, especially to determine the peculiarities of its distribution in the separate storm movements. It covers the period from January, 1885, when the Society had just entered upon its work and for which month 80 reports were received, through July, 1886, when the number of reports had nearly doubled. A grateful acknowledgment is made to

the trustees of the Elizabeth Thompson Science Fund for a grant, which has been devoted principally to the payment of the clerical assistance necessary for discussing so large an accumulation of material. and without which the investigation would not have been made. Much assistance has also been received from the U. S. Signal Service, whose daily weather maps and monthly Weather Review has been freely used, and whose observers in New England make regular reports to the Society. Special data not included in the regular reports have also been kindly furnished on several occasions by both voluntary observers of the Society and by the U. S. Signal Service.

The cyclones, whose passage over or near New England influence the prevailing weather conditions, are of very frequent occurrence. The word *cyclone* is here used, not as the synomyn of tornado or hurricane—its frequent use in the daily press—but as the general name for storm movements which are characterized by a centre of diminished pressure toward which the surface winds blow, circulating about the centre as they approach it in a direction contrary to the motion of clock hands. These storm movements may be classified into two general groups, (1) those which approach from the Great Lakes on the west,(2) those which approach from the south or southwest. The storms of the former class are the more numerous while those of the latter are in general more severe in the violence of the winds and and the amount of precipitation noted in New England. The former usually enter the country in the extreme northwest, move easterly over the Lakes and northwesterly down the St. Lawrence valley, north of New England. Not infrequently they move directly across New England from the Lakes to the Atlantic, instead of continuing down the St. Lawrence valley. Sometimes their origin is in the southwest and sometimes they enter the country from the Gulf of Mexico, proceeding northerly or northeasterly to the Lakes and thence approaching New England from the west. Occasionally, during the passage of a cyclone from the Lakes, a secondary development is formed in the Atlantic south of New England, which moves northerly until

the two unite; or a cyclone from the west may unite with one from the south, both approaching New England at the same time. The storms of the second group in their complete form, are the cyclones known as the West Indian hurricanes, which approach the United States in a northwesterly direction from equatorial regions, curve to the northeast in or near the Gulf of Mexico and move up the Atlantic coast, sometimes within the above line, sometimes wholly in the ocean. Frequently the cyclones of this group are developed in this country, north of the Gulf of Mexico or in the southern states, and occasionally one approaches the New England coast from the Alantic ocean, not having been earlier observed.

Of the cyclones of these two classes which had a prominent influence on New England weather in the nineteen months, January, 1885–July 1886, forty-one have been studied, embracing those which actually crossed New England or which passed sufciently near to show a marked effect upon its meteorological conditions. These will be treated in three divisions: (I) those of the first-class mentioned above, numbering twenty-two, (II) those of the second class numbering thirteen, (III) special cyclones in which a secondary development was formed on the Atlantic coast and in which two cyclones united, numbering six. The method of study has been: first to tabulate the data furnished by observers, and then to chart them upon maps of New England made upon a scale of thirty miles to the inch. These maps had been specially prepared for the purpose by the cyclostile process, and contained the position of each observing station carefully located. Further tabulations and charts were made, as suggested in the course of the work, which will be mentioned below. The authority for the storm tracks is the United States Signal Service, the tracks having been copied from the monthly Weather Review or the Daily Map of the Service.

I. CYCLONES APPROACHING NEW ENGLAND FROM THE WEST.

These may be considered in sub-divisions, (*a*) those which actually moved across New England, numbering fourteen of the

twenty-two, (*b*) those which moved just beyond the boundary,—the remaining eight; of the latter seven moved north of the boundary and one south. The following table gives in condensed form the general characteristics of each storm, preliminary to a more detailed discussion. In the column headed "date of passage" is given the date at which the centre of each depression was over New England, or passed at its nearest point to the district. The letters *d* or *i* following the barometric pressures indicate that the pressure was either diminishing or increasing as the storm moved along; in the former case the cyclone was gaining, in the latter losing in energy. Where neither of these letters is appended, the cyclone was moving without marked increase or decrease in its violence. The column containing maximum amount of precipitation gives not the highest single record, but generally the average of the three highest, as the design is to show the rainfall over a considerable area; in a few cases abnormally large records at individual stations, much exceeding those in the vicinity, have not been included for the same reason. The time of duration of the precipitation is reckoned from the stations in eastern Massachusetts only. The blanks in the table are explained in the current description of each storm.

TABLE I.—General characteristics of Cyclones.

A. Cyclones which moved from the west *across* New England.

Reference No.	Date of passage.	Pressure at centre. (inches)	Hourly Velocity. (Miles.)	PRECIPITATION.		
				Kind.	Max. am't. (inches.)	Duration. (Hours.)
1	...Jan. 17, 1885....	29.1 *d*	40	Rain & Snow.	2.0	48
2	...Feb. 1, 1885.....	29.4 *d*	32	Snow.	1.0	9
3	...Feb. 4. 1885.	29.3	35	Snow.	0.2	17
4	...Mar. 10, 1885....	29.4	46	Snow.	0.4	4
5	...April 13, 1885...	—— *i*	—	Rain & Snow.	0.3	—
6	...April 29, 1885...	29.2 *d*	20	Rain.	1 6	26
7	...June 29, 1885....	29.7	13	Rain.	3 3	48
8	...Sept. 9, 1885 ...	29 6	21	Rain.	1.9	35
9	...Nov. 19, 1885....	29.6 *d*	31	Rain.	0.9	7
10	...Dec. 19, 188	29.3 *d*	21	Snow.	—	—
11	...Jan 5, 1886.....	29.4 *d*	30	Rain & Snow.	2 5	—
12	...Feb. 20, 1886.....	29.1 *d*	40	Rain & Snow.	1.2	—
13	...Feb. 26, 1886.....	29.0 *d*	42	Rain & Snow.	2.7	30
14	...Mar. 9, 1886	29.7	42	Rain & Snow.	0.7	16
	B. Cyclones which moved from the west *near* New England.					
15	...Mar. 25, 1885....	29.8	36	Snow.	—	—
16	...June 5, 1885.....	29.6 *i*	—	Rain.	1.9	—
17	...July 10, 1885.....	29.6	20	Rain.	2 2	—
18	...Aug. 4, 1885.....	29.5 *i*	30	Rain.	5.4	16
19	.. Aug. 22, 1885.....	29.6	47	Rain.	1.9	—
20	...Oct. 14, 1885.....	29.4 *i*	19	Rain.	3.2	26
21	...June 3, 1886.....	29.5 *d*	31	Rain.	1.0	6
22	...July 16, 1886.. ..	29.7	—	Rain.	5.1	—

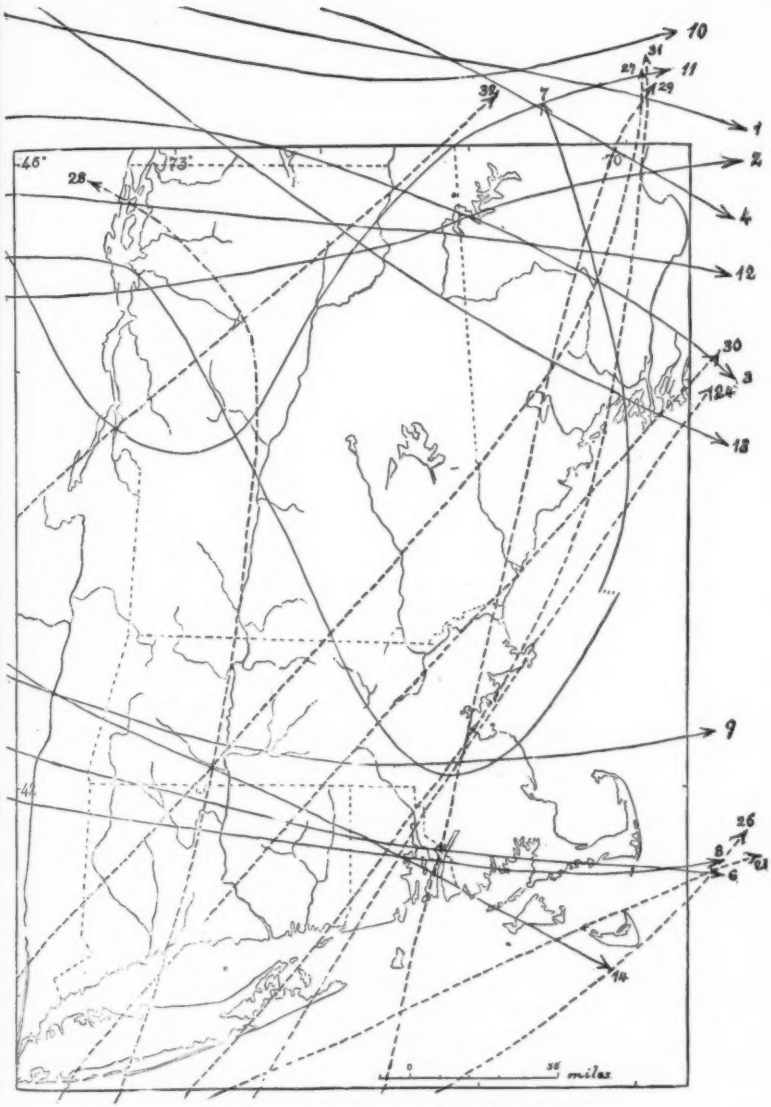

CHART I.—*Paths of Cyclones across New England.*

Full lines indicate cyclones approaching from the west; dotted lines those approaching from the south. The numbers are the current numbers in Tables I. and V.

In order to show graphically the paths followed by the cyclones which traversed New England, the accompanying chart has been drawn (Chart I.) It contains that part of New England in which all but a few of the reporting stations are located. Each track bears the number assigned to the cyclone in Table I. This chart also contains the tracks of the cyclones which crossed New England from the south, drawn in broken lines, for future reference. It will be noticed that the paths of the cyclones now under discussion fall into two distinct groups, one in the north, Nos. 1, 2, 3, 4, 10, 11, 12 and 13; and one in the south, Nos. 6, 8, 9 and 14. The track of No. 5 cannot be drawn, as the cyclone lost its definite form near the western boundary, and became dissipated over New England. No. 7 moved in an abnormal path: on reaching Massachusetts Bay it remained nearly stationary for a day, when it developed sufficient energy to resume its journey, and passed a second time over the district. The description of the individual storms should be read with constant reference to this chart and the data given in Table I.

A brief account of the characteristics of each of these cyclones will now be given.*

1. Jan. 17, 1885. This was a very severe storm which moved from Texas to the Lakes, thence across New England and the Atlantic Ocean to the Irish coast, which it reached on the fifth day after leaving the United States. The pressure diminished from 29.9 to 29.0 as it moved over the land. The precipitation was heavy, rain and snow mixed, and the maximum area lay over Massachusetts, Rhode Island and Connecticut.

2. Feb. 1, 1885. This was a moderate snow storm which entered the country in the northwest; after leaving the coast, it united with a severe cyclone which was moving in the Atlantic, and which reached the New England coast five days later. The snow was light, the maximum of 10 inches having been noted in northern Vermont, and the southern coast marking the limit of the precipitation.

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* The adjectives "severe" or "violent," when applied to storms, refer to the force of the wind and not to the character of the rain and snow.

3. Feb. 4, 1885. There was also a light snow storm moving in this country in a path similar to the preceding, and not known to have advanced far in the Atlantic. The distribution of the precipitation cannot be made out on account of the smallness of the snowfall, but was probably at its maximum in New Hampshire and Vermont.

4. Mar. 10, 1885. This cyclone moved in a path somewhat similar to the two preceding, but farther north. The precipitation was light snow, having its maximum of 4 inches in the north, and hardly noticed in the southern portion. The southern limit was probably near the coast, or about 300 miles from the central path.

5. Apr. 13, 1885. This cyclone approached from the Lakes on the 12th, with a central pressure of 29.6 inches, but dissipated over New England on the following day. The precipitation was light rain with some snow; it began on the 12th and continued in the form of occasional showers for two days. The maximum precipitation was in southern Vermont, and secondary maxima also occurred along the Merrimac river and in southeastern Connecticut. The least precipitation (which was of trifling amount) was noted in the extreme north and in western Connecticut.

6. Apr. 29, 1885. This cyclone approached from Colorado and disappeared in the Atlantic. As it passed over southeastern Massachusetts it was retarded, the velocity diminishing from 30 to 10 miles per hour. This retardation produced a similar tarrying in the duration of the rain; the time of ending of the rain on the eastern coast of Massachusetts having been nearly twelve hours later than at the Connecticut river. The heaviest rains occurred in northeastern Massachusetts.

7. June 29, 1885. This cyclone moved in a peculiar path and had marked characteristics. It moved from Lake Superior, crossing New England, on June 29th, in a southeasterly direction, but curving sharply to the northeast as it entered Massachusetts Bay. For about twenty-four hours it remained nearly stationary, when it again moved, and crossed western Maine in a northerly direction on July 1st; it again lost its energy, and

after existing for two days as a depression without a clearly defined centre, it was dissipated. The precipitation was heavy rain, with maxima exceeding 2 inches in eastern Massachusetts, northern Vermont and, especially, in southwestern Maine, where amounts of 4 inches and upwards were recorded. The fewness of the stations in Maine makes it impossible to determine the distribution in that state. The amount is clearly connected with the tarrying of the storm and its abnormal path. The rain came in a succession of showers which prevailed between June 28th and July 2d.*

8. Sept. 9, 1885.—This cyclone advanced from Colorado (probably having come from the Pacific Coast) and after leaving the United States moved in four days across the ocean to the British coast. It was not a severe storm, and the rainfall was less than one inch except in the northern part of New England, where it reached two inches.

9. Nov. 19, 1885.—This storm, which came from Dakota, also traveled across the Atlantic, passing from shore to shore in five days. As it crossed New England, it was attended by light rains which were heaviest in northern New Hampshire and Vermont. A marked peculiarity of the precipitation is that in eastern Massachusetts, near the path of the central depression, the rain did not begin until about five hours *after* the center had passed, its distance being about 130 miles eastward.

10. Dec. 19, 1885.—This cyclone traveled from the northwest, possibly having crossed the Rocky Mountains from the Pacific coast, and passed into the Atlantic. It was increasing in severity as it approached the coast, and the precipitation was in the form of snow. It has been found impossible to separate the records of snowfall belonging to this storm from those of several days immediately preceding and therefore its distribution cannot be determined.

11. Jan. 5, 1886.—This cyclone formed in Texas, moved to the Lakes, thence over New England and to the Gulf of St. Lawrence, as a storm of great severity. The winds were high but

*See "Thunder-storms in New England in the summer of 1885," by Prof. W. M. Davis, in Proc. Amer. Acad., July, 1886.

exceeded by those in the storm which followed four days later, and which was developed under the same conditions. This second storm will be especially treated in a subsequent section. The peculiar curve in the path of this storm is probably due to the development of a second centre on the morning of the 5th southwest of New England, which drew towards it the centre at that time over the Lake region. The rain and snow were heavy, showing maximum areas in western Connecticut and southwestern Maine. The times of beginning were, however, so varied that the duration of the snowfall cannot be accurately given.

12. Feb. 20, 1886.—This was a severe storm which came from the northwest and has been traced nearly across the Atlantic. As it crossed New England, rain and snow fell which reached their maximum in southwestern Maine. The storm ended in light snows at various times, rendering the determination of its duration uncertain.

13. Feb. 26, 1886.—This was one of the most violent storms on record as far as relates to the severity of the winds and their long continuance. It came from the northwest and passed into the ocean with increasing energy. The high pressures which followed closely after, caused such a steep gradient that the winds were of unwonted violence, and the maintenance of this gradient for several days while the storm centre remained nearly stationary in the Atlantic caused their long continuance. The intense cold following the storm gave additional discomfort to the severity of the winds. The temperature was mild preceding the storm and the form of the precipitation was rain and snow. It was large in amount, giving maxima exceeding two inches in southwestern Maine and southern Connecticut.

14. Mar. 9, 1886.—This was not a severe storm. It came from the northwest and has been traced to the Irish coast. It moved rapidly in this country and was five days in crossing the ocean. Light rain and snow attended its passage, and were heaviest in southwestern Maine, and lightest in Massachusetts near the central path of the cyclone.

15. Mar. 25, 1885.—This storm came from the northwest and moved northeasterly about 170 miles north of the northern

boundary of Vermont. It was attended by snows which in New England were not general. Probably the southern limit of the general precipitation was near the Vermont boundary. The sixteen stations reporting light snows are situated: seven on the coast, two in Connecticut near the coast, two in the mountains of Vermont, one in central New Hampshire, two in the Berkshire range, one in eastern New York, and one in Vermont near the northern boundary.

16. June 5, 1885.—This cyclone approached from Colorado, but curved to the southeast before reaching New England, and entered the ocean from northern New Jersey. The rains were heavy on the 5th, with light showers preceding, and were most abundant in northern Massachusetts, southern New Hampshire and Vermont.

17. July 10, 1885.—This well-developed cyclone passed 160 miles north of the Vermont and Canada boundary, on its northeastward path from Montana. It was attended by a series of showers which were especially severe on the 9th (see Prof. Davis' discussion referred to above). The rainfall between the 7th and 10th has maxima exceeding two inches in northern Vermont and in Rhode Island.

18. Aug. 4, 1885.—This cyclone came from Arkansas and moved northeasterly, passing 230 miles north of the northern boundary of Vermont. It was attended by remarkably heavy rains and thunder-showers on the 3d–5th, the principal amount falling on the 4th. The stations reporting more than five inches of rain are in southwestern Connecticut and central Massachusetts. The least rainfall was in the extreme northwestern corner of Vermont and the opposite southeastern corner of Massachusetts where the amounts were about 0.8 and 0.2 inches respectively. A trough of heavy rainfall exceeding two inches extended from southwest to northeast from 30 to 100 miles wide, and is parallel with the storm track, at a distance from it of about 300 miles.

This cyclone has been selected to illustrate the varied distribution of the precipitation in all the storms under discussion. (Chart II.) It is not peculiar in this respect, though few of the

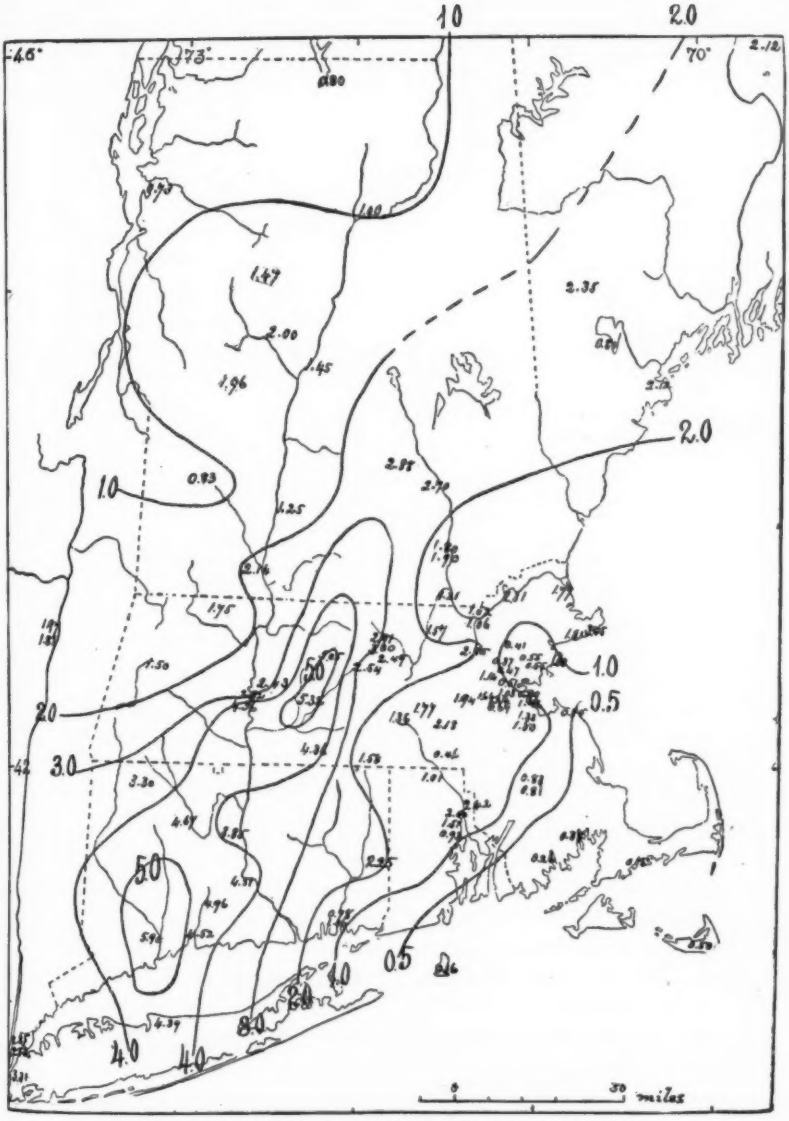

CHART II.—*Distribution of rainfall, August 3–5, 1885.*

The rainfall is given in inches; the full lines are lines of equal rainfall, drawn for every half-inch.

cyclones exhibit the parallelism in the region of heaviest precipitation to the path of the cyclone which is here shown. All, however, show that the amount of precipitation is not gradually progressive from the path of the cyclone outwards but is distributed unevenly, with clearly defined areas of maximum and minimum precipitation.

19. Aug. 22, 1885.—This cyclone entered the country in Minnesota and moved 200 miles north of Vermont in a northeasterly direction. Thunder-storms occurred on the 22d north of Rhode Island and Connecticut with abundant rains, especially in the Hudson valley at Albany. Local showers also occurred on the 21st.

20. Oct. 14, 1885.—This storm came from the West Indies, entered the country on the Florida coast, moved to the Lakes and then curved to the northeast. It passed 60 miles north of Vermont and crossed the extreme northern portion of Maine. The rains were excessive, over two inches having fallen in northern Rhode Island, and northeastern Massachusetts. The smallest amounts were at the stations in northern Vermont nearest the storm-path, and were less than 0.2 inch.

21. June 3, 1886.—This well-developed cyclone came from Kansas and passed our district 200 miles north of Vermont, moving northeasterly. The rains were light and show maxima of 1.0 inch in the Hudson valley and on the Maine coast and of 0.7 inch in northern Vermont. The rainfall did not begin until the storm centre had passed beyond its nearest position to the district.

22. July 16, 1886.—The path of this cyclone cannot be defined with the data at hand at the time of writing, but it moved from the Lakes northeasterly, far north of New England. The rains were heavy on the 14th and 15th, with a continuation of showers on the 16th and severe thunder-showers on the 18th. The amount between the 14th and 18th exceeded five inches at Setauket, Long Island, and exceeded three inches in the large area containing the state of Connecticut west of the Willimantic and Thames rivers, with a portion of southern Massachusetts

and eastern New York. But little rain fell in southeastern Massachusetts.

The foregoing description has been confined to a brief statement of the path of each cyclone, and a general statement regarding its precipitation. Further attention will now be given to the latter, for the study of which the principal data available are its amount, and the times of beginning and ending in each storm. There are many subjects which may be studied with the help of this material, such as the manner in which the precipitation is distributed in relation to the path of the cyclone, and its relation to the physical features of New England. It may be asked, too, whether each storm is peculiarly individual in its characteristics, a law to itself, or whether there are indications of general laws of distribution. The subjects of the rate of progression of the front and rear of the precipitation and its direction, compared with those of the storm centre, are also worthy of investigation. The difficulties in the way are the unavoidable uncertainty attending the data. The rain gauges are not of uniform accuracy and their exposure is varied; the danger from these causes has been reduced to its minimum by the special exertions which have been made to promote uniformity among the observers whose reports are accepted by the Society, but in a voluntary system this is only possible to a limited degree. A further difficulty arises from the great range in the readings of the best gauges at stations only a short distance apart, which must always necessitate caution in drawing generalizations from their records. There are also inherent difficulties in the records of the times of beginning and ending of precipitation. Oftentimes precipitation begins with light rains or snows occurring at irregular intervals, and the exact time to be noted is not apparent; a similar difficulty attends the cessation of the rain and snow. The times noted are therefore quite uncertain because the phenomena themselves may be incapable of exact determination. In summer thunder-storms, the rain begins as a rule with such definiteness that the time can be sharply determined, but in the general rains of a year this is not always the case.

The results of the study of the precipitation data may be indicated without a minute description of the details of the investigation. Tabulation and simple charting on maps of New England have been the means employed. Table II contains a summary of the facts obtained relating to the location of the area of greatest precipitation, and the distance and direction of the storm centre when the rain or snow began and ceased. The omissions are due to lack of sufficient data in certain instances to give results of value. A comparison of the values given in this table with the storm tracks pictured in Chart I, and with the brief descriptions of the storms, will throw much light upon their characteristics.

TABLE II. Relation of the precipitation to the path of the cyclone.

No.	Distance of max. area fr'm path. (miles).	Direction of max. area from path.	Distance of centre at begin. of prec'n. (miles.)	No. of Records.	Direct'n of centre at begin. of precip-itation.	Distance of centre at end of prec'n. (miles.)	No. of Records.	Direct'n of centre at end of precipi-tation.
1	250	S S W	1352 †	36	S W	243	27	N
2	20 ?	N ?	281	32	N W	189	30	N E
3	140	S W	326	20	N W	——	—	——
4	80 ?	S W ?	341	14	N W	——	—	——
5	——	——	250 *	16	N W	——	—	——
6	60	N N E	144	36	W	220 *	15	E
7	——	——	380 *	29	N W	——	—	——
8	180	N W	785	46	W	——	—	——
9	180	N W	130 *	20	E	326	49	E
11	190	S W	——	—	——	364	20	N W
12	50	S	379	58	N W	288	11	N W
13	30	N E	557	70	N W	——	—	——
14	160	N E	444	47	W	200 *	23	S E
16	240	N	——	—	——	220 *	13	S W
17	220	S E	350 *	18	N	——	—	——
18	430	S E	394	49	W	403	23	N
19	310	S E	367	16	N W	——	—	——
20	250	S S E	662	58	W	327	45	N W
21	320	S E	600	31	N N E	700	26	N N E
Av'ge Nos,								
1, 2, 3, 4, 11, 12, 13.....	94	S	377 ‡			271		•
6, 8, 9, 14.....	145	N	376			249		
17, 18, 19, 20, 21.....	306	S E	475			477		

* Distances thus marked were determined from stations in eastern Massachusetts only.
† Precipitation began while the cyclone was developing in the southwest.
‡ Omitting Number 1.

Attention has already been drawn to the fact that the storm tracks, illustrated in Chart I., fall into two distinct groups; those which cross New England in the north (Nos. 1, 2, 3, 4, 10, 11, 12 and 13) and those which cross in the south (Nos. 6, 8, 9 and 14). In the group whose paths lie outside of New England, all

except No. 16 passed north of the States in Canada. The averages appended to the table have been derived for each of these groups; it should be noticed, however, that the ranges are large and as the number of storms in each group is small, the numerical averages must be regarded as only a rough indication of the true averages of a large number of similar storms. Comparing the values of the distance of the centre when rain or snow began with the values of the amounts of precipitation in Table I., it will be seen that in general the greater the distance of the centre the larger is the precipitation, but this is not invariably the case, as in Nos. 1 and 20 compared with Nos. 13 and 18 respectively. Summer showers which may not begin until the storm centre is at its nearest point, or has even passed beyond it, often give more rain than accompanies other cyclones when the rain begins earlier and continues longer. WINSLOW UPTON.

[TO BE CONTINUED.]

THE CONNECTION BETWEEN METEOROLOGY AND TERRESTRIAL MAGNETISM.

PART I.

The results and inferences, from certain detailed experiments in the Physical Laboratory, designed to facilitate the explanation of phenomena connected with Terrestrial Magnetism, being somewhat extended, are offered in three separate papers, designed for publication in three successive numbers of the Journal.

(1) . Experiments and inferences bearing chiefly on secular manifestations or changes in declination, inclination and intensity, requiring for extreme changes several centuries, and, consequently, relatively termed the more permanent form of Terrestrial Magnetism.

(2) The Diurnal Solar changes, in the needle, which take place all over the globe, chiefly between the hours of 8 a. m. and 2 p. m. This slight variation is, in the northern hemisphere, to the west for the north-seeking end of the needle, but to the east, in the southern hemisphere. Under this head, some explanation will also be offered, why certain localities follow the north-

ern type, while the sun is north of the equator, and the southern type, when the sun is south of the equator.

(3) A solution is also offered of the anomaly in the Siberian oval, where, around that oval, there is no variation, while, within the oval, western declination exists as high as 5°, as well as of the anomalous oval in the Pacific Ocean, where the outer portions indicate as high as 8° of eastern declination, gradually decreasing to the center of the oval. In accordance with the above arrangement, the first subject to occupy our attention will be,

SECULAR, OR THE MORE PERMANENT FORM OF TERRESTRIAL MAGNETISM.

In detailing experiments connected with this subject, perhaps the citation of facts and laws already well known to scientists, may be excused, as facilitating intelligibility for the general reader.

Thus let us recall Oersted's law; that the needle *tends* to place itself at right angles to the current, and that when a rectilinear current is flowing for instance *west*, below the magnetic needle, the north seeking end of that needle will point *north*; but if the current is flowing *above*, then the needle points *south*.

To apply the law, however, to terrestrial magnetism, it becomes necessary somewhat to modify the experiment.

(1) If from a small box compass, we remove the lid, and then wind one turn of insulated wire from N. to S. or S. to N., if the current is very feeble, the needle may not reach its E. and W. position.

(2) Give, however, a dozen turns of the wire say from the pole of the battery, running from S. to N. at first *over* the box compass, then back underneath, and the N. seeking end of the needle will point due west.

(3) Uncoil one half of the wire, leaving six strands S. to N. and coil the other six from west over to east, the N. seeking end of the needle then points exactly half way between N. and W., viz.: N. 45° W., being the mean resultant of the two equal forces.

(4) The direction of the needle may be reversed by reversing the pole of the battery, or coiling in the opposite direction. With the above facts in view, let us now, on a Mercator map of

the world, lay down some of the most prominent isothermal lines, and place upon them at convenient distances, Roman crosses to represent the magnetic needle, giving to these crosses the suitable declination for a given period, as established for those localities. For convenience we many take the declination from Guyot's Physical geography, and the isothermals either from the same work or from any large reliable globe, on which the mean isothermal lines for January and for July are distinctly marked. The isocheimals, or mean winter isotherms, especially in America, run very closely in accord with the short cross bars of the Roman crosses, which necessarily represent the mean direction of electrical currents for those regions. Thus the isocheimals have their most southerly curves in South America, almost exactly beween Rio de Janeiro and the mouth of the Amazon, the agonic or line of no variation at that period and approximately so even now. In North America the curves very nearly mark the agonic from North Carolina, through Lake Erie, then west of James' Bay, to Boothia Felix. East of these curves, as they rise northerly, we find westerly variation, and west of these curves, easterly variation, the short cross bars of the needle according nearly with the curves. This would seem to justify us in concluding that there was some relation between the mean temperature of a place and its magnetic meridian, induced by geothermal electrical currents.

Let us further examine, how far the mean temperature of a given place, say Paris, agrees with the mean temperature of the earth's crust, at the depth which Humboldt terms the "invariable stratum." The greatest heat of July requires six months to reach this stratum, and so does the maximum cold of January. At ninety-two feet below the surface of Paris, the temperature is 53°.3, F., about 2° higher than the mean atmospheric temperature; and our wells *here* at 56° F. indicate approximately the mean annual temperature of this region. Within the tropics this invariable stratum is only a few feet below the surface, while in North Siberia, it was only reached at from three hundred to six hundred feet. Thus the invariable geothermasl seem to differ but little from the mean isothermals.

Our next inquiry may be directed to ascertain to what extent electrical currents circulate in the crust of the earth; how produced, and whether or not they have a connection with variable temperature.

GEOTHERMAL CURRENTS OF ELECTRICITY.

Some years since, in the campus of the Indiana University, where the subcarboniferous limestone comes near the surface, I drove long iron rods, nearly to the rock, and at various points of the compass, and connected them by insulated copper wire, with a sensitive galvanometer in the lecture room. Tri-daily observations, made for several months, showed that the prevalent currents flowed more or less westerly, although occasionally reversed for a brief period. The currents were usually stronger in the forenoon and afternoon than at noon, and were very weak after a thunder storm. The needle was often much agitated twenty-four to forty-eight hours before a thunder storm; violently so in the direction from Porto Cabello and Caracas to Indiana at the time of the great Caracas earthquake, April 12, 1878. The strongest mean currents for that portion of Indiana were from S. E. to N. W.

In laboratory experiments, when we apply heat at the junction of two dissimilar metals, and generate currents of electricity, these are stronger when the temperature of the metals at their junction is high than if it is low, as proved by the greater deflection of the enclosed magnetic needle. Hence we may infer that, as the earth in revolving from W. to E. exposes a given locality to the oblique rays of the morning sun, while on the same latitude, a place 6,000 miles east is having noonday fervor, there should arise a current of thermo-electricity flowing from E. to W. But at the same time as the tropics are much warmer than the polar regions, we may also expect currents from the equator to the poles, the resultants being the mean of those two forces. In the endeavor somewhat to imitate these forces, I constructed

AN ARTIFICIAL ELECTRICAL GLOBE,

which I figured and described in the St. Louis "Valley Natur-

alist" of October, 1878. Instead of this wooden globe revolving from west to east, insulated copper wire passed from the positive pole of a battery, and was coiled from E. to W. in grooves commencing at Lat. 70° N. and forming about 150 strands or coils before reaching Lat. 70° S., whence the wire extended to the negative pole of the battery, so that the electricity flowed from east to west. After starting the current, a magnetic needle carried around the globe, would give approximately the declination, as usually found in an agonic line through South America, and diagonally through North America, with for instance, 90° of western declination at Greenland, and 40 to 45° E. in Alaska, etc. Of course the anomalies, in Siberia and the Pacific, do not show on this model, but can be imitated as demonstrated hereafter. If the grooves had been cut nearly at right angles to the axis of the ecliptic, instead of to the terrestrial axis, the imitation of the phenomena of declination would have been more exact.

Even when, in the course of some centuries, the declination is very considerably modified, the relation at right angles to the isothermals still prevails approximately.

Many writers, as Reclus, Flammarion, Guyot, Mrs. Somerville, etc., consider that there are two cold poles in the Arctic region, and *probably* two similar within the Antarctic circle.

As Paris is not far N. W. of the pole of the land hemisphere in Switzerland, and magnetic observations have been made there since 1580, it is a convenient locality from which to draw inferences. In that year the declination was 11°, 20′, *east*; in 1663 there was no variation, the geographical and magnetic meridians coinciding; in 1814 the maximum western declination (22° 34′ W.) was attained; showing a probable oscillation for middle Europe, which is also the meridian of land center, of about 44° or 45°. If, however, we assume that the magnetic system has one pole of its central axis of oscillation at the intersection of the terrestrial equator with the meridian of land centre, as well as approximately with the magnetic equators of dip and intensity, then the angle moved through, in perhaps three centuries and a third, would be only one-half that of the angle at 45° or 46° N., consequently about 23° or 24°.

Assuming, as a working hypothesis, that the needle points to the colder Arctic pole, which in 1814 was in Boothia Felix and has since been gradually moving to the Siberian cold pole, which we further assume to be gradually becoming colder, while regions around Boothia Felix become slightly warmer, the movement in a direct line, would amount nearly to an average of six to seven geographical miles; or, up to this time, of between four and five hundred geographical miles. Under this supposition the north magnetic pole would be coming somewhat nearer Lady Franklin Bay, than in the beginning of the century, which proves to be a fact from official records. Because if nearer, then dip and intensity should have slightly increased; and in reply to a letter of inquiry, addressed to the Chief Signal officer, (through the geological department) as to whether or not dip and intensity had recently slightly increased in Lady Franklin Bay, Gen'l Hazen courteously replied that such had been the case between the periods of observation by the Eng. Expl. Exp. in 1876, and that of the Greeley Exp. ending August, 1883.

As regards the decrease of cold in the western Arctic regions and gradual increase in the eastern, I have been unable to find sufficient data for reliable results; but those obtainable are favorable to the hypothesis. To enumerate them in detail would make this communication exceed the proper limit. The next will be an endeavor to elucidate the Solar Diurnal variation.

RICHARD OWEN.

LOOMIS' CONTRIBUTION TO METEOROLOGY.

THE PROGRESSIVE MOVEMENT OF STORMS.

"After an area of low barometer has been formed, it soon begins to change its position."—Loomis' 8th paper.

DIRECTION OF MOTION.

In his twenty-first paper, Loomis gives a chart on which are drawn the tracks of all the important storms of the northern hemisphere which had been delineated up to that time [1885] on the monthly Signal Service and International bulletins.

"From this chart we see that north of the parallel of 30°

storm tracks in all longitudes almost invariably pursue an easterly course, but generally they show an inclination toward the north of east; while within the tropics storm tracks almost invariably tend westerly, with an inclination toward the north of west."

In the tropics near the West Indies "the average course of the cyclones, enumerated in my fifth paper, while they were moving westward, was 26° north of west; and the average course of those enumerated in my fourteenth paper during the same part of their course, was 26½° north of west. * * * The average course of the cyclones originating near the China sea and Bay of Bengal, as enumerated in my fourteenth paper, was 38° north of west as long as they were moving westerly."—Loomis' 21st paper.

Loomis also found that north of the parallel of 30° the direction of the storm tracks varied with the longitude. He determined the average direction of the tracks at each 10° of longitude on the Atlantic Ocean for the four years 1878–81 and obtained the following table:

Longitude.....	60	50	40	30	20	10
Average latitude....	46.9°	48.9°	51.3°	53.9°	54.9°	55.5
Storm track.....	N. 68° E	N. 67° E	N. 67° E	N. 70° E	N. 75° E	N. 79 E.

In the western part of the Atlantic the direction of the tracks were pretty much the same throughout the year; but in the eastern part, they varied from about N. 70° E in summer to N 90° E in winter.

A similar determination of the average direction of storm tracks at stations in the northern part of the United States, between the Rocky Mountains and the meridian of 90° gave the following:

Station.	Bismark	Fort Sully	Breckenridge	North Platte	Yankton	Omaha	Pembina	St. Paul	Dubuque
Storm track.	N 107° 7 E	N 106.7 E	N 105.5 E	N 104.1 E	N 106.3 E	N 100.8 E	N 109.4 E	N 99.3 E	N 88.3 E

"We see that at the more western stations the average movement of storm centres is toward a point considerably south of of East, but at the more eastern stations the direction is a little north of east."—Loomis' 21st paper.

Individual storms, however, frequently show marked deviation from these average movements. Sometimes storms will remain almost stationary for several days.—Loomis' 5th and 8th papers.

Sometimes in the middle latitudes they will move almost directly north or south. Loomis found from the published observations of the Signal Service eight cases in the United States during the seven years (1872–78) in which storms moved almost directly toward the north, and six cases in which storms moved almost directly toward the south.—Loomis' 11th paper.

Movements for several days towards the south-east, and toward the north-east, are quite common. Loomis found in the United States, sixteen cases in six years (1874–79), in which storms moved toward the south-east as far as the parallel of 28°; and thirty-three cases in which storms came from as far south as 26° and advanced toward the north and east. The former were almost entirely confined to the winter and spring, and the latter "class occurred most frequently in the autumn and least frequently in summer." "None of the storms which have pursued a south-east course across the United States and its vicinity, have been traced farther south than latitude 22½°, and only three have been traced as far south as latitude 25°. These storms during their progress southward generally decline in intensity. Some of them decline to such an extent that their course can no longer be traced."—Loomis' 14th paper.

Occasionally storms in the middle latitudes will move toward some westerly point for a short time—in extreme cases for a day or two. Loomis found thirteen such cases in the United States during six years 1873–78); and nine cases in Europe and eleven on the Atlantic Ocean during five years (1875–1880)—Loomis' 14th paper.

VELOCITY OF STORM PROGRESS.

The following table gives the average rate of the progressive

movement of storms as found by Loomis in various parts of the northern hemisphere:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
United States	33.8	34.2	31.5	27.5	25.5	24.4	21.6	27.6	24.7	27 6	29.9	33.4	28.2
Atlantic Ocean	17.4	19.5	19.7	19.4	16.6	17.5	15.8	16.3	17.2	18.7	20.0	18.3	18.0
Europe	17.4	18.0	17.5	16.2	14.7	15.8	14.2	14.0	17.3	19.0	18.6	17.9	1s.7
West Indies								14.4	14.0	12.8			13.7
Bay of Bengal and China Sea				7.5	8.5	5.6	8.4	10.3	9.8	9.2	7 4		8.4

These results are obtained from thirteen years observations in the United States, five years in Europe, four years on the Atlantic Ocean, seven months in the West Indies, and one year in the Bay of Bengal and China Sea, and are given in miles per hour.

It is seen that the velocity of storm movement is greatest in the United States, and least in the Bay of Bengal. * * "In the United States, the average velocity of movement for the entire year is about two-thirds greater than it is in Europe. This ratio is greatest in winter when it amounts to 1.9; and least in autumn, when it amounts to 1.5."—Loomis' 21st paper.

ANNUAL AND DIURNAL VARIATION IN THE VELOCITY OF STORM PROGRESS.

"We see from this table that the average velocity of progress of storms for the entire year [in the United States] is 28.2 miles; also, that the velocity is greatest in February and least in August, and that the former velocity is 50 per cent greater than the latter. * * * The velocity varies very much for the same month in different years, the greatest mean velocity for the months of April and October being more than double the least mean velocity for the same months."—Loomis 21st paper.

Loomis also found a diurnal periodicity in the velocity of storms in the United States. The average velocity of storm progress during 1873 and 1874 was 25.4 miles per hour between 11 P. M., and 7:35 A. M., 25.9 miles per hour between 7:35 A. M. ad 4:35 P. M., and 31.9 miles per hour between 4:35 P. M. and 11 P. M. "* * * It appears that the average velocity of storms from 4:35 P. M. to 11 P. M., is about 25 per cent. greater than it is for the remainder of the day. This excess varies for the dif-

ferent months, ranging from 14 to 32 per cent. but in each month the most rapid progress occurs during the same portion of the day."—Loomis' 3d paper.

STORMS MOVING WITH UNUSUAL VELOCITY.

Both in Europe and the United States storms sometimes move 1,000 miles a day. Loomis tabulated "all of the cases in 1876 and 1877 in which storm centres [in Europe] advanced over 1,000 miles in twenty-four hours"; and says: It will be seen that the number of European cases in which storms advance 1,000 miles in a day, amounts to 11 in two years, being an average of 5½ cases annually; the greatest rate of progress observed is 1330 miles in a day. These storms generally advanced toward a point north of east, and in no case was there a considerable movement toward the south of east, and they were all accompanied by winds of great violence.

In the United States, the cases in which storms advance with a high velocity are of much more frequent occurrence, and they sometimes attain a velocity greater than has been observed in Europe, but the amount of the barometric depression is much less."

Loomis tabulated all of the cases in the United States from September, 1872 to January 1875 and from January to March 1877 in which storms advanced at least 1,000 miles a day. "The number of cases in the table is 39, occurring within a period of 32 months, which gives an average of 14 per year, being 2½ times as many as occur in Europe. The greatest observed velocity of these low areas was 1872 miles per day, which is 40 per cent. greater than the highest velocity observed in Europe. The average height of the barometer at the beginning of the days enumerated was 29.62 inches, and the average height at the end of the days was 29.42 inches, which is only half of the depression observed in the storms of Europe. In 27 of the cases the depression at the centre of the storm increased during the day, in 11 cases it decreased, and in one case it remained stationary. * * * Thus we see that in the American cases the storms generally increased in intensity, while in the European cases there was a slight diminution of intensity."—Loomis' 12th paper.

STORM PROGRESS AS INFLUENCED BY THE EXTENT OF BAROMETRIC DEPRESSION AT THE STORM CENTRE.

Taking the published observations of the signal service during 1872 and 1873, Loomis "compared the height of the barometer at the centre of each storm with its height at the same place 24 hours before and also 24 hours afterward." By this method of comparison "it was ascertained that the velocity with which the storm advances is independent of the amount of barometric depression at the center of the storm, and it is not sensibly affected by the circumstances, whether the pressure at the center of the storm is increasing or diminishing."—Loomis' 1st paper.

STORM PROGRESS NOT PREVENTED BY HIGH MOUNTAINS.

In his 9th and 13th papers Loomis shows by means of curves giving the variations in pressure at successive stations, by means of isabnormal lines, by means of isobars drawn from the pressure reduced to sea level, and by means of wind changes, that storms frequently pass from the western across to the eastern side of the rocky mountains, and he says: "It seems then, to be clearly established that barometric waves frequently travel from the Pacific coast across the Rocky mountains and reach the Mississippi valley with but little modification. The Rocky mountains form an uninterrupted barrier 6,000 feet in height from British America southward to latitude 32°, and the Sierra Nevadas present a barrier of the same height extending from British America southward to latitude 36°, with but three interruptions, amounting in the aggregate to less than 100 miles. The Rocky mountains form a barrier of 10,000 feet in height which extends nearly half the distance from latitude 49° to latitude 32° and which is continuous for about 350 miles in the vicinity of Colorado. The Sierra Nevadas also present short ranges of equal altitude, but the longest of them is less than 150 miles.

Thus we see that an unbroken mountain range of 6,000 feet in height cannot stop the progress of atmospheric waves; neither do ranges of more than 10,000 feet in height, broken as in North America, present any insuperable obstacle.—Loomis' 9th paper.

CAUSE OF THE PROGRESSIVE MOVEMENT OF STORMS.

" * * * In the middle latitudes of the northern hemisphere there is a remarkable correspondence between the average direction of the progress of storms and the average direction of the wind as shown by Coffins' wind charts." " * * In the middle latitudes storms almost invariably move toward the east, and the opposite movement only occurs occasionally, and seldom continues longer than one or two days. This fact seems to result from the prevalent movement of the wind toward the east." "Some meteorologists have claimed that the progressive movement of storm areas is satisfactorily explained by saying that they are carried forward by the general movement of the mass of the atmosphere within which they are formed; that is they *drift* in a sense similar to that in which waves, eddies, etc., formed on the surface of a river, drift with the current." —Loomis' 21st paper.

A close examination, however, shows that there is no exact relation between the two. "* * * The average direction of movement of areas of low barometer does not generally co-incide with the average direction of the wind for the same region. This is seen not only in the case of tropical storms, but also in storms of the middle latitudes." "The average course of West India cyclones, while moving westward, differs from 28° to 30° from the average course of the wind." "The average course of the cyclones originating near the China Sea and Bay of Bengal, as enumerated in my fourteenth paper, was 38° north of west, as long as they were moving westerly." The average course of the wind in this region is found to be south 33° west from July to September, and north 47° east for October and November. "For the first three months the average direction of the progress of storms is 35° north of west, and for the last two months it is 25½° north of west, that is during the first period the average course of storms differs 88° from the average direction of the wind, and during the last period the difference is 68½°. We also perceive that a change of 166° in the average direction of the wind is accompanied by a change of only 9½° in the average direction of the progress of storms."

Loomis determined the average direction of storms and the average direction of the wind at a number of stations in the northern part of the United States, between the Rocky mountains and the Mississippi river, and found that "at Bismark and Fort Sully the average course of the winds is 50° more southerly than that of storm paths; while at St. Paul, LaCrosse and Pembina it is 22° more northerly." Loomis also determined the deviation of the average wind direction from the average storm track at each ten degrees of longitude on the Atlantic ocean, and gives the following results:

Longitude	60°	50°	40°	30°	20°	10°
Wind most northerly	−37.7°	−21.5°	+5.1°	−1.3°	+16.3°	+27.6°

"We see that for the middle of the Atlantic ocean near the parallel of 50° the average direction of storm paths corresponds very closely with that of the average progress of the wind, but in the western part of the Atlantic the average course of storms is 30° more northerly than that of the wind, while in the eastern part it is 30° more southerly."

Neither is the velocity of storms proportional to the velocity of the wind at different parts of the earth's surface. In the United States "the mean velocity of the wind is only one-third as great as over the Atlantic ocean, but storms travel with nearly double velocity. * * The same anomaly is found when we compare the storms of the United States with those of Europe. In northern Europe the surface winds have a velocity greater than those of the United States, and we may infer that the same is true for elevations of 1,000 or 2,000 feet above the surface; yet storms in Europe advance with but little more than half the velocity of those in the United States. There must then be a powerful cause which accelerates the movement of storm areas in the United States, and which does not operate in Europe or over the Atlantic ocean, and apparently the same cause does not operate in southern Asia, or the West Indies, at least in an equal degree."—Loomis' 21st paper.

[There is every reason for believing that the velocity of the upper air over the Atlantic is as great as, and probably greater than,

it is over the continents, since the observations on high mountains show that the velocity of the upper air over the continents is retarded by the uprising of the lower heated air; so that it evident that the average velocity of storms is not proportional to the average velocity of the atmospheric movement in which it is immersed. The retardation of the upper air is found to be greatest in the afternoon, which is the time Loomis has found storm progress to be greatest, so that this too seems to show that the movement of the upper air is not the controlling cause of the movement of storms.]

"But it may be claimed that the progress of storm areas is not determined by the average movement of the atmosphere, but by that movement which is taking place at the date of the storm. There is some reason to think that in the case of tropical cyclones, particularly in the China sea, the wind which generally prevails at the time of the cyclone accords more nearly with the direction of the storm's progress than does the average wind for the same season of the year, but there is no evidence that there is an exact agreement between these two directions." "If we open a volume of [Signal Service or Hoffmeyer's] maps, anywhere at random, we shall not find the general mass of the atmosphere surrounding a great storm moving forward in the same direction as that in which the storm advances."

"Besides these general considerations there are various special phenomena which indicate that the movement of areas of low pressure cannot be fully explained by the theory of a general drift of the atmosphere. We frequently find two neighboring low areas advancing in directions inclined to each other at an angle of 45°, or even a greater angle. In the United States, while a low centre is advancing from Florida along the Atlantic coast toward the northeast, another low centre may be advancing eastward over the region of the Great Lakes, and the two low centres may coalesce somewhere in the neighborhood of Nova Scotia or Newfoundland. * * * Newfoundland becomes thus a point of convergence of storm tracks proceeding from regions quite remote from each other. In the vicinity of Newfoundland, there exists some influence which appears to act as an attractive force upon storm centres."

There are "other points toward which storm tracks seem to converge, particularly the Asiatic coast near Japan."

"It sometimes happens that within an area of low pressure having but a single centre, a second low centre is developed. * * * In a majority of these cases, the two low centres appear to have subsequently coalesced; but in several of them, the two low centres moved off in directions inclined to each other at an angle of 90° or more, and with unequal velocities.

Over the Atlantic ocean and Europe, cases similar to the preceding are of much more frequent occurrence than in the United States; the depression of the barometer is generally much greater and the low areas have a much greater geographical extent. * * * Sometimes there is further change by which three or four or even more low centres are formed, and these low centres have a progressive movement in different directions, and with unequal velocities. * * * In cases like these, it surely will not be claimed that the movement of the low centres can be ascribed to a simple drifting of the general mass of the atmosphere in which the low areas were formed."—Loomis' 21st paper.

To what other cause or causes, then, can the progressive movements of storms be ascribed? "According to the theory advocated by the late Mr. Espy, when the vapor of the atmosphere is condensed, its latent heat is liberated, which raises the temperature of the surrounding air, causing it to expand and overflow laterally in all directions in the upper regions of the atmosphere, thus causing a diminished pressure over the region of precipitation and an increased pressure on all sides beyond the area of rain. * * * The storm works its own way eastward in consequence of the greater precipitation on the eastern side of the storm. Thus the barometer is continually falling on the east side of the storm, and rising on the west side."—Loomis' 1st paper.

This hypothesis serves to explain many of the phenomena connected with storm movements. Loomis points out that in the United States east of the Rocky mountains the greatest bodies of water, the dampest air, and the greatest precipitation are on the east side of storms.

Hourly observations of the rainfall made for three years at Girard college show "that at Philadelphia the amount of rain which falls while the barometer is descending, is nearly three times as great as that which falls while the barometer is rising, and during the six colder months of the year the rainfall in the former case is nearly five times as great as in the latter." Hourly rainfall observations, or observations every two or three hours, at various points in Europe show that "at the stations near the west coast of Great Britain and Ireland, the amount of rain with a falling barometer is more than twice that with a rising barometer, but this ratio rapidly diminishes as we advance eastward. At Paris this ratio is reduced to one and a half, and in central Europe more rain falls while the barometer is ascending than while it is descending." "These facts seem to indicate that in Europe the center of the rain area must precede the center of least pressure by a less distance than it does in the UnitedStates" and serves to explain why storms move more rapidly in the United States than in Europe.

"Upon the Atlantic Ocean the vapor on the western side of storm centers generally has a greater tension than it has upon the eastern side, owing to the warm water of the Gulf stream. In my eighth paper I have endeavored to show that in the vicinity of Newfoundland storms are frequently delayed several days, and this result is apparently due to the abundant precipitation of vapor in that region."—Loomis 12th paper.

H. HELM CLAYTON.

[TO BE CONTINUED.]

WEATHER TYPES ON THE PACIFIC COAST.*

By W. A. GLASSFORD, 2d Lieut. Signal Corps, U. S. A. Assistant.

A short study of the charted weather reports of the Pacific coast, reveals certain types lasting for a considerable period which admit of classification. East of the Rocky Mountains, however, no such characteristics are present; the storms or

*From the *Bulletin of the California Academy of Sciences*, Vol. II, No. 5, September, 1886. The plates are not reproduced.

cyclonic areas, as well as the anti-cyclonic or areas of high pressure, generally originate in the Gulf of Mexico, the Rocky Mountain slopes, or in British America, and move in succession over a curved path almost invariably to the eastward at a uniform rate, and with uniform characteristics. They disappear as regularly near Nova Scotia. It is very seldom, if ever, that perfect paths of low pressure areas are traced from the Pacific coast across the mountain plateaus and ranges, although some few cases have been charted on the storm track maps; but even these are not so uniform as in the East, for they frequently tarry for quite a period, clinging to some valley or plateau. On this coast a noticeable feature is the difference in the storm frequency between the northern and southern boundary lines of the United States. Areas of low pressure of any intensity are of infrequent occurrence in southern California, but going north become more frequent as Vancouver island is approached. From a search of the Weather Reviews for three years, it is found that areas of low pressure entering the Pacific coast states from the ocean during that period number 90; those north of the 45th parallel are 54; between 45° and 40°, 25; between 40° and 35°, 10; below the 35th parallel, 1. Another peculiarity of the areas of high and low pressure here is their arrangement in recurring and symmetrical types; recurring, because there is a tendency to assume the barometric condition on successive days; symmetrical, because the recurrence as denoted by the barometer takes about the same area, shape and intensity.

Except the November, and the greater storm of January last, and in fact the centers of these were the whole time at sea, there has been no distinct cyclonic area, such as appear in the Eastern States, central over California during the past season. Those who examine the Signal Service synoptic charts with its reports may have observed "High" and "Low" designated, but these are often such only by contrast; the areas where the group of barometic readings, reduced to sea level, are the greatest or the least that appear on the map, being so named.

Another observation may be noted. When severe and stormy

weather prevails on this coast, and especially in California, almost invariably the press dispatches announce from the East the prevalence of cold waves, snow blockades, tornadoes, etc. If complaint be made at any time that the climate of the Pacific coast is in no way superior to the ordinary Eastern weather, attention may be drawn to the fact that at that time cold waves, snows, etc., prevail over the East; if here the winds are high, they are balanced by tornadoes or hurricanes there; if washouts delay travel on this slope, floods in the streams of the great Eastern valleys and seaboard do vastly more damage; if frosts nip the buds in our California citrus belt, in Florida oranges are frozen. Such is the action of storms on this Coast relative to the margin of the great Arctic high pressure ridges which surge down from British Columbia. These coincidences show a common sensitiveness to distant weather conditions. Contrary to the usual rule in the states east of the Rocky mountains, we have observed here a recurrence and persistence of fine clear weather, or of rainy days, for quite a period. The interruptions are slight, of short duration, and the prevalent types are unmistakable. The synoptic charts during these periods show a general resemblance. For instance, during February last scarcely any rain fell. In April we had almost constant rain from the 1st to the 17th, then followed suddenly clear weather to the month's end and after. The fact that the change from one type to another is so very sudden is what causes the difficulty on this coast in forecasting the weather. These phenomena, as aids to forecasting, I call weather types.

This study is only possible by reference to the reports of the observations taken three times a day simultaneously at 4 A. M., noon, and 7 P. M., Pacific time, telegraphed to San Francisco and charted by entry on outline maps. Isobars and isotherms are drawn showing the belts or areas of like pressure and temperature, and symbols are added marking stations where rain has fallen or cloudiness exists. It is seen that map after map, day after day is almost identical. A persistence of some one barometric characteristic covers the same region. Applying the principle of composite photography, taking a transparent out-

line map of the same scale as the weather map and drawing lines enclosing like areas, and continuing this process on the same transparent map, we have represented a great number of like areas superimposed upon each other.

We thus find the high or low barometer regions to correspond with certain characteristic conditions of cloudiness and rain, which remain stationary and hover over the same locality during the continuance of the high or low. For instance, grouping all the charts that have high pressure over Oregon, and the low over southeastern California, it is noticed that remarkably fine weather with northwesterly winds continues for a succession of days, while this condition lasts. When the barometer changes, it does so suddenly, and the weather changes with equal rapidity. The greater the number of these like features of barometer and weather found, the greater, of course, is the frequency of the type. Illustrating in the case of February last, it is found that a persistent high overlay the district embracing Oregon with parts of Nevada and Idaho.

Indeed, if only the observations of a single station are studied, taking a specific instance of the recurrence of a persistent weather type, the list of days in which rain of any consequence fell on successive days in San Francisco during the last rainy season, shows six such periods lasting from six to fifteen days each. These periods of the rainy season, and the contrasting conditions of rain absence intervening, are the special object of this inquiry.

I now come to determining and naming these weather types, commencing with the rainy season of 1885–6. On November 1st, the first interruption of the dry season of 1885, disregarding some slight rains occurring prior to this date, began at the time when the high, which had moved inward from the coast with the advance of the season and finally hung stationary over the eastern slope of the Cascade range, moved further eastward before the low area advancing on the Washington territory coast from the sea. This low area spread south and brought the rainy season for San Francisco and this portion of the State. This type I call the

NORTH PACIFIC CYCLONIC.

It prevailed from November 1st to 10th, and from January 11th to 14th, and is distinguished by a low barometer area of considerable depth over and to the westward of Oregon and Washington Territory, which, striking the mountain range and high pressure to the eastward, cannot break over the barrier, and is held there with fluctuating depth for some time.

The high, which always exists somewhere in the margin of the low, continues central in the district north of Salt Lake. During the prevalence of this type, southerly gales occur from cape Mendocino to Vancouver island. Rain prevails and frequently becomes heavy over Oregon, Washington Territory, in California south to San Luis Obispo and in the San Joaquin Valley. The temperature throughout the cost is about normal. It is only when a subsidiary low is developed in southeastern California, locally called a "Sonora storm," that rain spreads over the southern part of the state, being generally of short duration.

INTERIOR ANTI-CYCLONIC.

This second type closely resembles the preceding in that the interior high is well marked, but differs in that the low upon the coast is less in depth. This type prevailed from November 11th to 15th; Noxember 25th to December 6th; December 14th to 16th; January 27th to February 12th. It is characterized by a high barometer (about 30.30 inches) over Utah, Nevada and southern Idaho. The accompanying low barometer on the northern coast drops down frequently to 29.70, and is central west of Washington territory. These lows appear to beat against the high, the low area often dropping down for a short time nearly to cape Mendocino. At other times they push the high southerly over Arizona and pass eastward beyond our boundary. Again when the surge of high pressure is very great over Idaho, a low often pushes upon it from the southwest coast of California, at which time rain may occur in light showers on the southern coast. The rainfall, except as just mentioned, never passes south of San Francisco, and is generally limited to light showers in Oregon and Washington territory. Gales are very

strong from the southeasterly at cape Mendocino and at the mouth of the Columbia river, north of which they come more from the south. The temperature is usually high, and at times, of steep gradients, from Nevada southward; near Los Angeles, the warm "Santa Anna" winds may occur.

NORTH PACIFIC ANTI-CYCLONIC TYPE.

This type is very frequent, but sometimes of short duration. It prevailed from November 10th to 15th; December 7th to 13th; December 31st to January 10th; February 12th to 21st; February 23d to 25th; March 10th to 12th; March 23d to 28th; April 2d to 5th, and April 17th to 29th. While this type is prevalent the high, as is implied by its name, rests over Oregon and Washington territory, with a permanent low over southern California. It is attended with clear weather, only interrupted by an occasional shower near Vancouver island. During its prevalence in its perfection and greatest intensity, and while the isobars are perpendicular to the coast line, is the time when the dreaded dessicating "north wind" prevails in the Sacramento and San Joaquin valleys. The temperature is high during the day, especially after several days' continuance of the type, while at night frosts often occur. The winds are usually light and variable on the coast of Washington territory and Oregon, but on the coast of California high with southerly gales. If in the spring, during the prevalence of this type high winds and sandstorms occur in southern California, they are almost sure to be followed by rain. The proverb that a succession of frosts is liable to be followed by rainy weather, obtains warrant from the fact that the breaking up of this type is usually foretold by frosts and most certainly followed by rain. The occurrence of this type on the first ten days of January, 1886, appears to bear a certain relation to the great surges of high pressure from the Arctic regions moving well westward over British Columbia. The isobar of 30.3 to 30.5 inches enclosed the area. The weather on the coast was unusually cool and clear; frosts extended into southern California. During this period remarkably cold weather was prevailing in the Eastern States. These surges of

high pressure in their movement covering almost the width of the continent during the first ten days of January, caused the development of intense cyclonic areas originating in the Gulf of Mexico or Texas and moving northeastward along the Atlantic coast, accompanied by the most severe cold wave of the year east of the Rocky mountains.

THE GENERAL CYCLONIC TYPE.

This type is characterized by the most severe storms that occur on this coast. The rain area overspreads all sections, falling in torrents, and gales of the greatest violence with frequent thunderstorms occur, rivers overflow, and washouts impede travel. The barometer drops very low and suffers rapid fluctuations, and remarkable gradients occur between the coast and interior. Simultaneous with this type is a series of exceedingly high pressure waves over the Rocky mountain plateau and states to the eastward, accompanied by severe storms and intense cold. During the last season there were only two occurrences of this type, viz., from November 15th to 25th, and January 25th to 26th. The general feature is a cyclonic disturbance on the Pacific coast line, which, apparently unable to cross over the Sierra Nevada, seems to spread out over the entire length of our region, until it gradually wastes away or finds escape beyond the limits of our field of observation. The occurrence of this type in January last is especially worthy of careful review. On the 15th another surge of high pressure followed the north Pacific anti-cyclonic of the first ten days of January, extending from British America over the Rocky Mountain region. On this coast was developed a series of storms among the severest in the history of the country. The temperature was very low in Montana, and spread its influence over portions of this coast, causing frost, snow, ice and unusual cold in portions of the Pacific states. Rains were heavy and almost continuous, gales frequent and severe, needing no description to those who were here at the time. The storm, as represented by the barometer, was a series of most extraordinary fluctuations; the disturbance would suddenly appear at any given station, and after a few hours be scarcely preceptible, only

again to appear at this or some other station. A diagram showing these fluctuations is interesting. The center appeared for a time to be over the interior valleys of California, and not great in depth, and it was only upon consulting ship-reports that it was found that the eye of the storm was far to the westward. This center appeared first upon the coast about 3 A. M., January 20th, off Point Conception, where the roughest weather was experienced. A few hours later it was reported off the mouth of the Columbia river. From 5 to 8 A. M., about 175 miles southwest of San Francisco, the *Zealandia* was in the southeast and southwest hurricane, with the glass at 29.23. The barometer, about the same time at San Francisco, was 29.31 inches; at 8 A. M., at Cape Mendocino, the barometer fell to 29.15, with the wind a hundred miles per hour from the S. E.; at noon it was 29.06, with the wind from the southeast and blowing with hurricane violence, carrying away the anemometer, after which accurate observations were interrupted for a few hours. At the same time the wind was southwesterly at San Francisco, blowing 42 miles, but at Point Lobos, the south head of Golden Gate, six miles away, it was 96 miles an hour. The cyclone was off the coast of Oregon at 7 A. M., as shown by a pressure of 29.17; but by the following morning, the 21st, at 4 A. M., the pressure had risen, and the cyclone had completely vanished from the charts, and by 12 M. the isobar of 30.20 passed from Washington Territory through Oregon down to the center of California and out near San Luis Obispo. But one other isobar (30.10), drawing isobars for every tenth of an inch, appeared on the chart, and this enclosed northwest Washington Territory. The next morning (22d) the cyclone reappeared at the mouth of the Columbia River, here also carrying away the anemometer. It again subsided, and burst in once more the same day at the Straits of Juan de Fuca, the glass going down to 29.00. Again almost disappearing, it came in upon the Washington territory coast the 26th, the baromenter falling this time to 29.15. On the 27th it was not to be seen, and if it passed eastward it did so far beyond the northern boundary.

During this time severe washouts occurred in Southern Cali-

fornia, and the telegraph lines were everywhere prostrated. I find this type is not a frequent one, and it comes only in such intensity as described at long intervals. The great storms of 1875 and 1879 are the only ones that can be ranked with this one.

The next distinct type is the

SOUTH PACIFIC ANTI-CYCLONIC,

which appears as a moderate high along the southwestern California coast. It is peculiar on account of the rains which accompany it, being one of those types which bring out many inquiries from those having and observing barometers, asking the question, how it is that we have rain with so high a barometer. It creates isobars somewhat perpendicular to the coast, bringing in the rain-bearing southerly winds at San Francisco. It is noteworthy that any type exhibiting isobars perpendicular to the coast line is almost sure to bring rain, while if the isobars are parallel to the coast, fair weather follows. This type was in existence from March 31st to April 2d, and from April 7th to 17th. During its prevalence a faint low may exist in the north Pacific. Rain occurs in the interior California valleys and northward, also in the vicinity of Los Angeles. Should the general pressure fall considerably below the normal, but with the relatively high barometer continuing in the same region, gales with thunder and hail storms are frequent in southern California. The winds are not strong north of San Francisco, except when the barometer becomes very low, and such cases are few. This type disappears by the movement of the high along the coast into Oregon, and ceases very suddenly. The temperature is unusually low.

SUB-NORMAL TYPE.

This type is marked by a succession of days when the pressure is moderately low, and below the normal over a large area. The isobars are broken up, are wavy or enclose several subsidiary low areas, with an absence of any decided gradients. This type prevailed from February 26th to March 4th, and from April 5th to 7th. Rain at intervals occurs, frequent local storms, and thunder storms are reported. Occasionally a gale, but local

in character, does considerable damage. The winds are variable, and the weather cool and cloudy.

It might be well to add that the changes occurring in the cyclonic types follow a general principle that a disturbed equipoise recovers itself in proportion to the intensity and rate which the disturbance has originally developed. The greater the high, the greater the depth of the low which follows, and if the change is sudden, the appearance of the opposite condition is sudden. In meteorology, as in mechanics, these vibrations of the disturbed equipoise are liable to continue for some time in waves of gradually decreasing length before coming to rest; and the observance of this principle enables us to say that a disturbance is not definitely passed although the synoptic charts give but little indication of its recurrence.

The dry season demands only the briefest consideration, having but one general characteristic—high pressure over the sea and low over the land. The type of the dry season has about the sameness of the weather which accompanies it. The high is greatest and most persistent over the ocean and north Pacific coast, and lowest from Arizona to Nevada including eastern California. Almost the only peculiar feature of the type is the occasional low over the central valleys of California.

Rain is almost entirely absent when this type becomes perfectly established, and only occurs in light showers in Oregon and Washington territory, when the high happens to drop down well on the California coast, creating a condition similar to that of the "South Pacific Anti-Cyclonic Type," already described. Another feature of the dry season is the development of considerable intensity of the high in Oregon, the pressure being at the same time very low in southern California, creating the northerly winds in the Sacramento and San Joaquin valleys.

The boundary between the wet and dry season would, I believe, be as definite as the sun's march north or south if not for these disturbing weather types, which bring into effect conditions overriding the gradual change of temperature. It is well established that the temperature of the Pacific Ocean differs very little anywhere on the coast, and the monthly variation is

so slight that it may be disregarded. We can in a general discussion say that the temperature of the ocean washing our shores is about constant. It is wholly different over the land, and the difference increases in proportion to the distance from the sea. In the winter, the prevalent type is such as to drive the ocean winds over a country where the temperature is cooler than themselves, and where the condensing conditions are strong enough to well deplete them of moisture; hence rain results upon the western slopes and little remains for the Rocky Mountain country. During the summer, on the contrary, the winds from the Pacific Ocean passing at once over the drying country, do not precipitate their moisture at all till the Rocky Mountain summits condense them. Thus the rainy season is transferred from this coast to these higher regions. The change of one season to another is best illustrated by projecting the curve of surface temperature of the Pacific Ocean, with the mean daily temperature of a place in proximity to it, for instance, San Francisco. As soon as the air temperature curve permanently crosses the former, the change of season takes place. A specific case of this principle is discussed and well illustrated in the last Bulletin of this Academy, by Prof. Davidson, in his paper on the air and water temperature at the Golden Gate.

CORRESPONDENCE.

THE CHARACTER AND PATHS OF STORMS; INFLUENCE OF TOPOGRAPHY.

To the Editors:—For eighteen years, in Dakota, I have as a surveyor been outdoors much, and have, therefore, watched the weather closely. The dweller in tents is in them only to sleep. He sees the whole sky from sunrise to sunset daily for months. He learns the "signs" the winds and clouds give him. The wide, unbroken plains give extensive views. One sees the entire progress of a storm from its first cloud to its last.

In 1883, we were in camp just north of the 40th parallel, about 50 miles west of the Minnesota line, about 10 miles north of the northwest corner and highest point of the *Coteau* which lies west of Traverse and Big Stone lakes. Mount Airy, as the highest point is called, rises several

hundred feet above the plain. It was late in the summer, the day was warm, and probably the pressure low. Looking toward the summit, we saw a misty cloud about it. This increased in breadth, and extended higher in the air. In a half hour a slight shower appeared from it, and lightning. A gentle breeze rose from the W. N. W., the cloud extended, and moved E. S. E. along the northeast edge of the elevated lands. Within an hour and a half all that quarter of the heavens was a dense rain-cloud, with much electric display. A few days later, from the St. Paul *Pioneer-Press* I read an account of a great rain-storm that passed down the Upper Minnesota Valley that afternoon and night, and spread over southeast Minnesota, and continued to Chicago and Milwaukee, or beyond. There were no clouds west or north of that beginning that day and most of the next. That was evidently the beginning of that extensive rain-storm.

On another occasion we were traveling toward the Black Hills by the stage-coach, from the southeast. We saw Harney's Peak, their highest point, and in the hot afternoon a cloud-cap formed about its summit, followed later by lightning, and a thunder-storm that passed southeasterly across the plains.

There are limited regions in Dakota much more subject to hail-storms than the general area. These tracts are southeast or east of ridges or areas of considerable elevation. Indeed, this fact has been so long and well known as to enable one to determine, without experience and before settlement, where hail would most likely occur. Hail is not so apt to occur, it seems, upon an elevated region or table-land, as to the southeast of it, and on lower lands. Speaking with a settler about this tendency, he replied that he lived on the east edge of the very wide plain of the Dakota River Valley, and just at the west foot of the *Coteau* above mentioned, and that he had suffered from a severe hail-storm. He added, however, that this storm came from the northeast, which is altogether unusual, but it thus followed the supposed rule.

About September 1, 1880, we were traveling south from the Northern Pacific R. R. about 50 miles west of Fargo, upon the high land just east of the Cheyenne River, and thus on the extreme west edge of the valley of the Red River of the North. From such a point one sees over a large part of that valley, which is an inclined plane toward the east. About two o'clock we stopped for dinner upon a swell, higher than the country near, and saw a cloud form upon higher hills many miles north of us. It grew rapidly, and in an hour or more was an immense mass of very dark clouds, with electrical display, moving slowly in a course a little south of east. We drove on toward the south upon our journey, and to keep clear of the storm. By half-past four it was northeast of us, and had the typical form of a tornado. It began to show this form earlier, and remained in sight till nearly six o'clock. Its motion along its path could

not have been over fifteen miles an hour. It did not always touch the earth. It widened rapidly toward the top, and was crowned by a great and irregular mass of black clouds. In the middle and upper parts it was marked by rapid pulsations of lightning. We knew it was a tornado, and watched it closely. When we were, perhaps, fifteen or twenty miles from it at the nearest point, the wind was variable, blowing in little gusts first one way and then another. There had been a high wind from the south for two days, and this grew warmer until the tornado formed. It was then oppressively hot. After the tornado a northwest wind followed, continuing two days, and it grew quite cool. We heard of the storm later, and it was of a destructive character, though the settlement was sparse and little damage was done.

The course of this tornado would not pass far from St. Cloud, Minn., the scene of the tornado of last spring. The other tornadoes in Minnesota have been in the valley of the Upper Minnesota, at and near New Ulm, and at Rochester, upon an extension of the same course. This is in a line southeast of the *Coteau* above mentioned, west of Traverse and Big Stone lakes. We have noted other severe wind and rain storms along the same path, and a destructive hail-storm this summer, marking some parts of that region as more subject to storms than adjoining regions.

Yankton is in the Missouri valley, upon the bank of that stream, and is not subject to dangerous wind or hail storms. When the latter reach us at all, they come from, and are traceable to, the Wessington hills and adjacent highlands, over a hundred miles distant. From the mouth of the Niobrara to Sioux City, Iowa, the course of the Missouri is but little south of east. To the north of it the country is smooth and little elevated. To the south it is much higher and more broken. In eighteen years the more severe wind-storms of summer have passed along those higher lands south of the river. The hurricane which two years ago damaged Sioux City, and blew from the track a train of cars in the extreme southeast corner of Dakota, passed along that elevated land about ten miles from, and parallel to, the Missouri, till it reached the great bend near Sioux City, where it crossed the valley and maintained its general course, spreading wider as it progressed.

These are a few observed instances, and others might be added. They have suggested to those who have not studied meteorological science, and lack a wide view of the conditions of such storms, that features of topography such as the Coteaus, the Black Hills, and less important groups of hills or ridges, may have a formative or modifying power over storms, of great importance. Other well-known conditions of a wider and more general influence are the occasions of storms, but these may so mingle or direct these forces as to change the character of the storms. Such storms as those mentioned are not merely the general summer storms, with winds of moderate or high force. They pass over the whole prairie Northwest, toward the southeast, like a tidal wave of wind, stretching from near Lake Superior to Topeka. They pass over in a few hours at most; while the blizzard of winter may blow over the same region as long as three days. The storms we mention occur in areas of low barometer, and are veins or narrow lines of special force in a general stormy condition. Do they have relation to topography for their special character?

W. H. H. BEADLE.

YANKTON, DAK., September 4, 1886.

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